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Evaporation in Kansas.

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The state of Kansas, with its eastern boundary touching the Missouri river valley, and its western boundary lying in the midst of an area once popularly known as the great American desert, lies in an important climatic tension zone of the United States.

Eastern Kansas has an average annual rainfall of 35.25 inches, based upon thirty-one years of observation. During the same period the western division of the state has had an average rainfall of only 19.19 inches. And the central portion is just between, with an average of 26.24 inches per year. This difference in rainfall, connected directly, as it must be, with differences in relative humidity and evaporation intensity of the atmosphere, is one of the dominant climatic factors which determine the character of the native vegetation of the state; and the native plants of eastern and western Kansas are as widely different as one might expect from the difference in annual precipitation.

Measured in terms of crop production, a 19 to 35 inch rainfall, if properly distributed through the growing season, and utilized only by the crop growing on the land (a condition impossible of realization, of course), is sufficient for the production of from 60 to 105 bushels of wheat per acre. This estimate is based upon a water requirement for wheat of 500 pounds of water for each pound of dry matter produced, and assumes that grain and straw are produced in the proportion of two pounds of grain to three pounds of dry straw.

What becomes of the rainfall is therefore a problem of great interest in this great agricultural center of North America, where we think we do well if we average 25 bushels of wheat to the acre. Very frequently it happens that distribution of the rainfall is not favorable for maximum plant growth, and lack of moisture more often than any other condition becomes a limiting factor in crop production.

Of course, everyone knows that part of the rainfall is lost as run-off water before it has a chance to penetrate the soil. But a considerable part of the water does soak into the ground and becomes a part of the great subsurface reservoir of water which fills our wells, forms the source of the waters found in our permanent drainage systems, and furnishes the supply of moisture to the roots of growing plants. A third portion of the water evaporates from the soil surface, and from the leaf surfaces of vegetation. It is this loss which becomes serious when dry weather is prolonged, and the efforts of the farmer must be directed toward reducing direct soil evaporation to a minimum. Whatever loss occurs from the soil should always be confined, so far as possible, to the transpiration of living plants, if maximum yield is to be obtained.

Just how much water evaporates from the soil itself during a growing season is not known. It must depend on many factors, and vary greatly with soil type, configuration of the surface, methods of culture, climatic conditions, etc. But it would be of vital interest to know how much water goes out of our fields on days when atmospheric evaporation intensity reaches its maximum. Unfortunately, there is no simple means of determining the amount of water lost from the soil day by day as a drouth proceeds. But we can measure the evaporating power of the atmosphere by measuring the actual work accomplished by the climatic factors causing evaporation.

Although the weather bureau has been in operation twenty-eight years, it is only recently that it has become properly interested in the evaporating power of the air as a factor in crop production and weather conditions in general. While a good many observations of various kinds are on record, the conditions under which the observations have been taken are so diverse that comparison of one locality directly with another is entirely out of question. In order to secure comparable data it was necessary to standardize the methods of taking observations. This has been brought about by the establishment recently of what are known as Standard Class A Evaporation stations in various localities, principally in the arid and semi-arid regions of the United States.

The Standard Class A station is constructed according to specifications furnished by the government, and consists of an evaporation pan four feet in diameter and ten inches deep, which is filled with water to a depth of seven or eight inches, and freely exposed to air and sunlight. A round brass cylinder called a still well sits in this pan of water and protects the water surface within it from being ruffled by the wind. This makes accurate readings possible. An accurate measuring instrument known as a hook gage is set on top of this well, and the level of the water in the pan is measured every day at a certain hour. The gage is constructed to read to the thousandth of an inch. In addition to the pan there is a rain gage to correct the readings of the level in case of precipitation, an anemometer to measure the wind flow across the surface of the pan, and a pair of thermometers to give the daily temperature range. All of these instruments are arranged according to a standard plan, and enclosed by a standardized net wire fence designed to offer little obstruction to light and air currents. By having every feature standardized every station is as near like all the rest as it can be made, and the readings from different stations can be compared directly. The first of these stations to be established was the Mitchell, Neb., station, which began observations in April, 1911, under the reclamation service. But in 1915, a model Class A station was established at the American University, Washington, D. C., which began its observations on April 18, 1915. Two other stations were established in 1915, one at Gardiner, Maine, and one at the Roosevelt dam in Arizona.

During the meeting of the Botanical Society of America held at Columbus, O., in December, 1915, a public announcement was made that the government had decided to attack the evaporation problem in earnest, and expected to establish a number of stations in advantageous locations. During 1916 twenty-five stations were established, and two were added in 1917. On January 1, 1918, therefore, there were thirty stations on the continental United States, and one at San Juan, Porto Rico. The map shown on plate I gives the locations of all active stations except San Juan.

Two of the stations were located in Kansas, one at Lawrence, under the auspices of the botany department of the University of Kansas, and one at Tribune, under the auspices of the Kansas State Agricultural College. The Lawrence station began its readings on August 7, 1916, and the Tribune station on August 16, 1916, in the midst of the serious drouth of that year.

The data which have been accumulated during the last two years are yet too meager to permit of any generalizations, but the mere facts have proved to be so interesting that they deserve to be made public.

The evaporation day by day has been plotted in the form of curves for the thirteen months during which observations have been possible. The winter months are omitted, of course, because the freezing of the water would endanger the pan and still well, and would make accurate readings impossible. The curves are shown on plates II to XIV.

These curves are very irregular, due to rapidly changing conditions of temperature, wind velocity, and relative humidity. The high points are often associated with high temperature, or brisk winds, or both in extreme cases. Unfortunately relative humidity data are not collected by these stations. The low points correspond to periods of rainfall, or low temperature, or light winds, or combinations of these conditions.

While each of the curves presents certain points of interest, the most striking one is plate X, for July, 1917, which illustrates the development of serious drouth conditions. The spring rains ceased on June 5, several weeks earlier than usual, and thereafter rainfall occurred as mere traces, or in insignificant amounts until August 6. About the middle of July (13-15), there were several small rains, following which the evaporation increased steadily to the end of the month, reaching on July 30 the highest daily rate ever recorded at the station, .709 inch. The maximum temperature was above 100° every day for the last six days preceding the 30th, and the wind velocity was high and constantly increasing during the last four days of this period. This climax to the long dry period came very near to being ruinous to crops, and would have been exceedingly destructive if copious rains had not fallen at the end of the first week in August.

It is interesting to note that the average daily evaporation during the drouth of August, 1916, was .330 inch per day, and the average daily evaporation for the drouth of July, 1917, was .357 inch per day. Perhaps it is not going too far to say that whenever the evaporation reaches an average of about .350 inch per day for a week or two at a time, drouth conditions are rapidly approached in eastern Kansas. The evaporation will not reach this level and maintain it until the weather has been dry for some time, and the soil has become too dry to contribute much to the humidity of the atmosphere. As long as the soil has a good supply of moisture near the surface, the evaporation does not reach the drouth level continuously, even though there is no rainfall.

A comparison of the evaporation with rainfall month by month is most interesting. And the surprising thing about it is the almost constant excess of evaporation over rainfall. The rainfall exceeded evaporation in only two months out of the thirteen recorded, and one of these, November, 1916, would not have shown an excess if the whole month had been recorded. The record was terminated by severe freezing weather on November 13, a few days after a heavy rainfall.

If we divide the evaporation for any month by the rainfall for that month, the quotient gives a number which is known as the monthly evaporation-rainfall ratio. The evaporation-rainfall ratio for the months so far recorded, including the parts of months in August and November, 1916, are shown in table 1.

TABLE 1.

Year.	Month.	Evaporation.	Rainfall.	Evaporation-rainfall Ratio.
1916.	August (25 days)	8.245	.99	8.33
	September	7.761	3.21	2.42
	October	5.128	3.82	1.34
	November (12 days)	2.012	3.03	.66
	Total, 1916	23.146	11.05	2.09
1917.	March	5.953	1.55	3.84
	April	5.681	3.39	1.68
	May	5.701	3.97	1.44
	June	8.385	2.11	3.97
	July	11.061	.50	22.12
	August	6.956	4.69	1.48
	September	5.445	5.70	.95
	October	4.114	1.37	3.00
	November	3.079	.02	153.95
	Total, 1917	56.378	23.30	2.42

The mean daily evaporation for each month is shown in plate XV. The annual curve of evaporation intensity indicated by these means are much more closely related to temperature and humidity than to wind velocity, for surface wind velocity is highest in spring and fall, when the vegetation offers least resistance to air flow, while the lowest average wind velocities occur in midsummer or later, when vegetation is at its maximum development. In March the surface velocity was about four times as great as in August and September, and in November it was about twice as great as in September.

Comparison of the evaporation in western Kansas with that in eastern Kansas can be made as yet only in a fragmentary way, owing to the incompleteness of the records from the Tribune station. Only four complete monthly records have been made at Tribune, and the comparative data for these months at Lawrence and Tribune are shown in table 2.

TABLE 2.

Year.	Month.	Tribune.	Lawrence.	Difference.
1916.	September	9.347	7.761	1.586
1917.	April	6.880	5.681	1.199
	May	7.689	5.701	1.988
	September	8.494	5.445	3.049

From this table it is seen that the evaporation is from one to three inches per month greater in the western part of the state than in the eastern part. During a season this would amount to perhaps eighteen inches. It seems fair to conclude that the evaporation intensity of the atmosphere is on the average about 25 per cent greater at Tribune than at Lawrence. At the same time the precipitation is 45 per cent less at Tribune than at Lawrence, based upon the average annual precipitation for the eastern and western divisions of the state.

If the evaporation from the open pan actually represented water loss from the soil, Kansas long ago would have been a hopeless desert, for the evaporation measured in this way will always be greatly in excess of precipitation. The season's evaporation would amount to almost 6,400 tons of water per acre, or for the whole state approximately 350 billion tons—enough to produce nearly a billion tons of dry forage, if it could all be evaporated through the leaves of plants.

It is not to be supposed, of course, that the data obtained enable us even to guess at the actual loss of water from the soil, for as soon as the top layer of the soil becomes dry it forms a protecting blanket against the effects of the dry atmosphere, especially if it is kept loose-textured and well-tilled. But we can, after a fashion, grasp the significance of the intense evaporating power of the air to the living plant. The leaves of plants contain a high percentage of water, and they are exposed freely to the drying power of the air, which is believed to be equivalent on an ordinary dry day to nearly a thousand atmospheres of force. That is, when an object is becoming air dry, the molecules of water are extracted from the substance at least with a force of about fourteen thousand pounds per square inch. All of the moisture lost by the plant under the influence of these tremendous atmospheric forces must be made good by the actively absorbing roots, and if they fail to keep up with the drying process, wilting must occur. If the failure is by a narrow margin, wilting is only temporary, but even this greatly reduces plant production, while if the failure is severe, permanent wilting and death ensue.

One of the most important problems just ahead, therefore, is to determine the relation of evaporation from the standard pan to evaporation from the soil. On a day when the evaporation from the pan reaches 5 inch, how much drier does the soil become at a depth of six inches, or eighteen inches, where the mass of plant roots are located? And when we have a whole month of dry weather, how rapidly is the soil water depleted? What influence has soil type on the rate of water loss? What difference is there in the rate of water loss from fields of corn, wheat, etc., and on fallow land? These problems involve many complex factors, and may be very difficult to solve. But during the coming season it is hoped that a study can be made of several selected localities in Douglas county, with the purpose of determining the relation of atmospheric evaporation intensity, as measured by the Standard Class A Evaporation station, to the rate of disappearance of water from the soil itself. Such a study, aside from its scientific interest, should be of considerable practical importance.